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ENGINEERING RESEARCH IN AIR POLLUTION

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1974

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U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Public Health Service

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ENGINEERING RESEARCH IN AIR POLLUTION

U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Public Health Service

Division of Air Pollution
Laboratory of Engineering
and Physical Sciences

Robert A. Taft Sanitary Engineering Center
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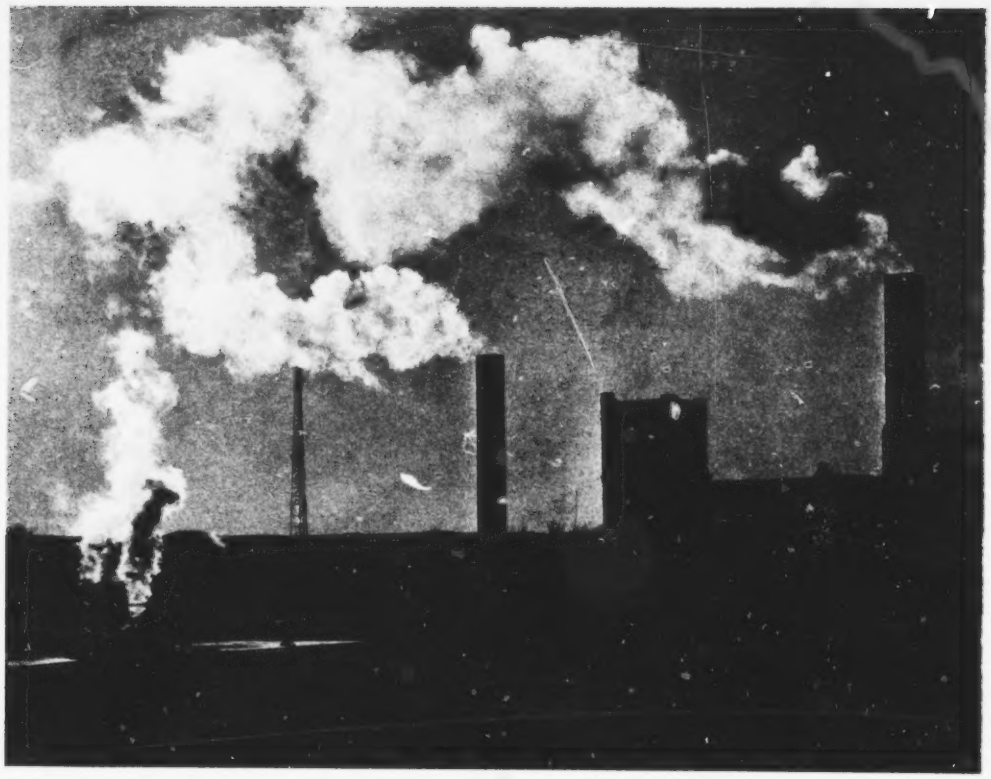


Pollutants fill the air over American communities. Not only in industrial centers, but in the heart of towns and cities, in residential neighborhoods, on heavily traveled thoroughfares —the daily discharge of pollutants contaminates the air we breathe.

Foreword

In the Public Health Service program of air pollution research the engineer works with chemists, meteorologists, physicians, and scientists of many other disciplines, whose major concern is a single element of man's environment: polluted air. The air pollution engineer approaches his work with a special point of view. When he examines a working mechanism he considers it not only in terms of its function but also as an air pollution source. His chief task is to find answers to these two important questions:

- Where do air pollutants come from?
- What can be done to reduce air pollution at its sources?

These questions can be answered only in terms of specific air pollution problems. The approach of PHS engineers to the solution of some typical problems is described on the following pages.

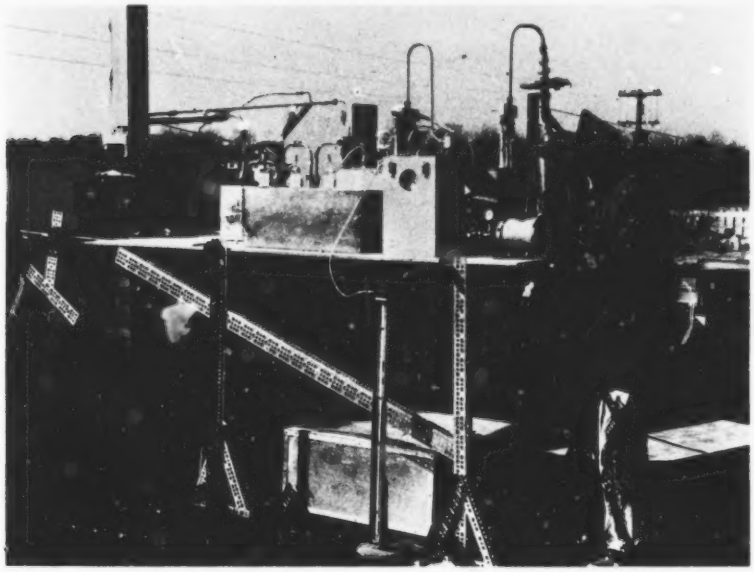
A Fundamental Problem:

EVALUATING AIR POLLUTION SOURCES

Where do air pollutants come from? Since pollutants enter the air from a great many sources, it is often difficult to determine the origin of components of a given air parcel. In considering the many possible sources of air pollution, the engineer assesses those that seem to be most significant in community pollution problems. He recognizes major classes of polluting sources and determines the relationships among them. For example, many man-made pollutants are produced by burning and are carried into the atmosphere in the combustion gases. These combustion sources are diverse:

- an industrial plant
- a municipal incinerator
- a household furnace
- an automobile engine
- a cigarette

Each involves burning, often with incomplete combustion of the 'fuel,' and each emits a stream of gas that may be loaded with contaminants. Part of the work of the engineer is to discern, among such varied sources, certain basic similarities in the mechanisms of pollution.

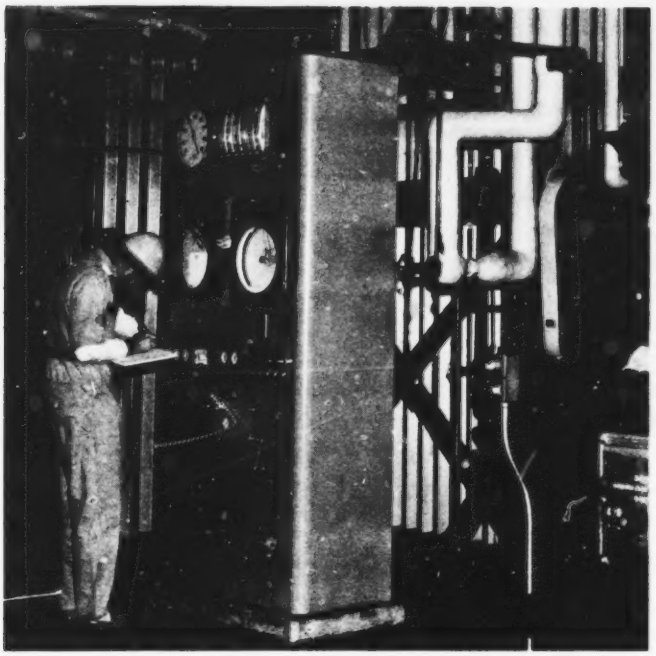


Sampling on a rooftop for emissions from a household furnace

Recognizing these similarities, the engineer still must determine what pollutants are emitted from particular sources, and in what quantities. For this purpose emission survey teams are equipped with a variety of instruments to obtain samples of the air at the emission points of significant pollution sources. Laboratory analyses by air pollution chemists then reveal what the samples contain.

For special projects the survey teams may sample in search of a particular type of pollutant. For one such project, engineers are examining possible sources of polynuclear hydrocarbons such as benzpyrene, a compound that interests medical researchers because of its possible health effects.

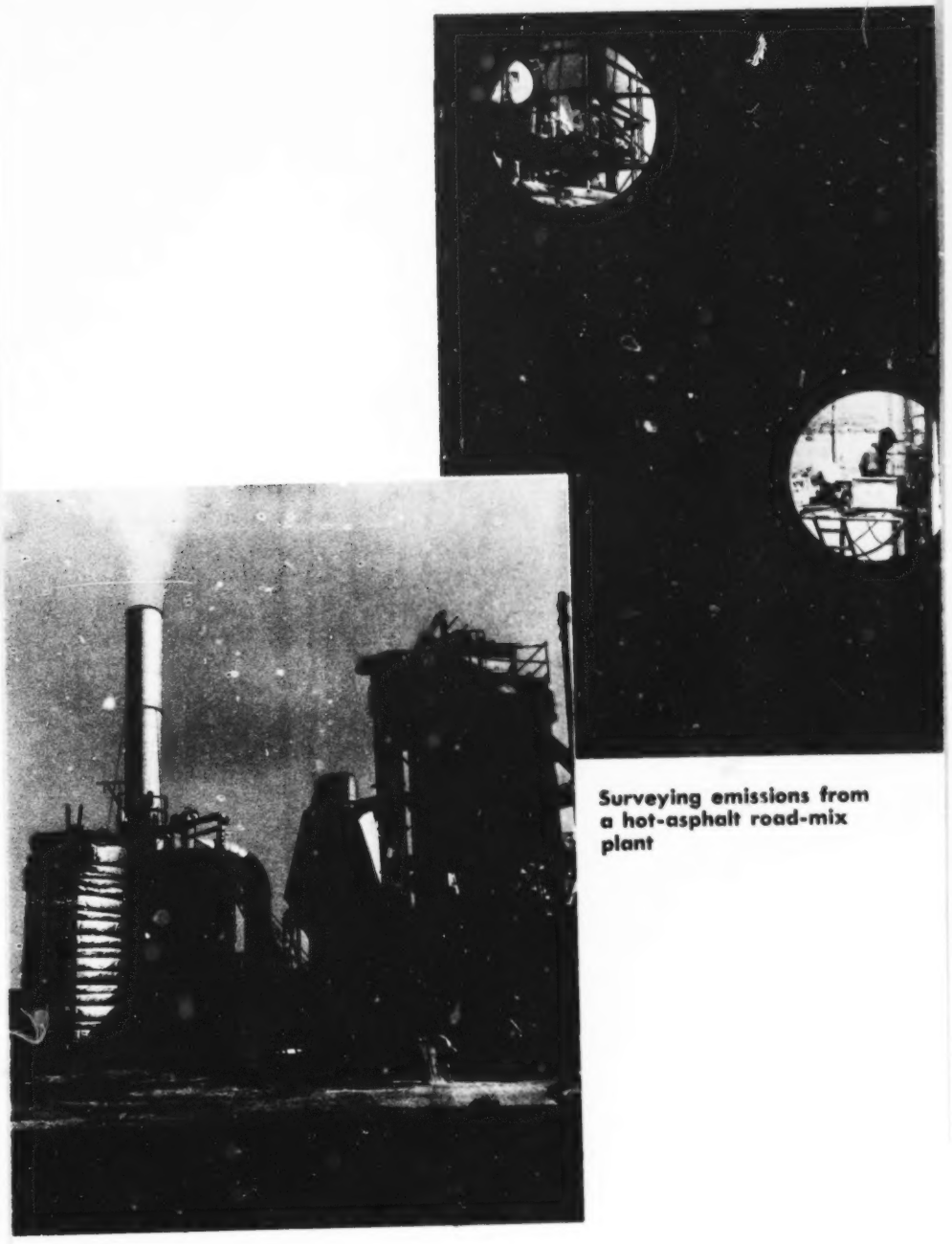
More often, however, samples are secured for evaluation of a system's total air polluting properties. What pollutants does the air stream carry? In what amounts? For such evaluations the engineer selects a typical installation that can represent a class of similar operations. The survey team samples the gas stream under all normal operating conditions, which are recorded in detail.



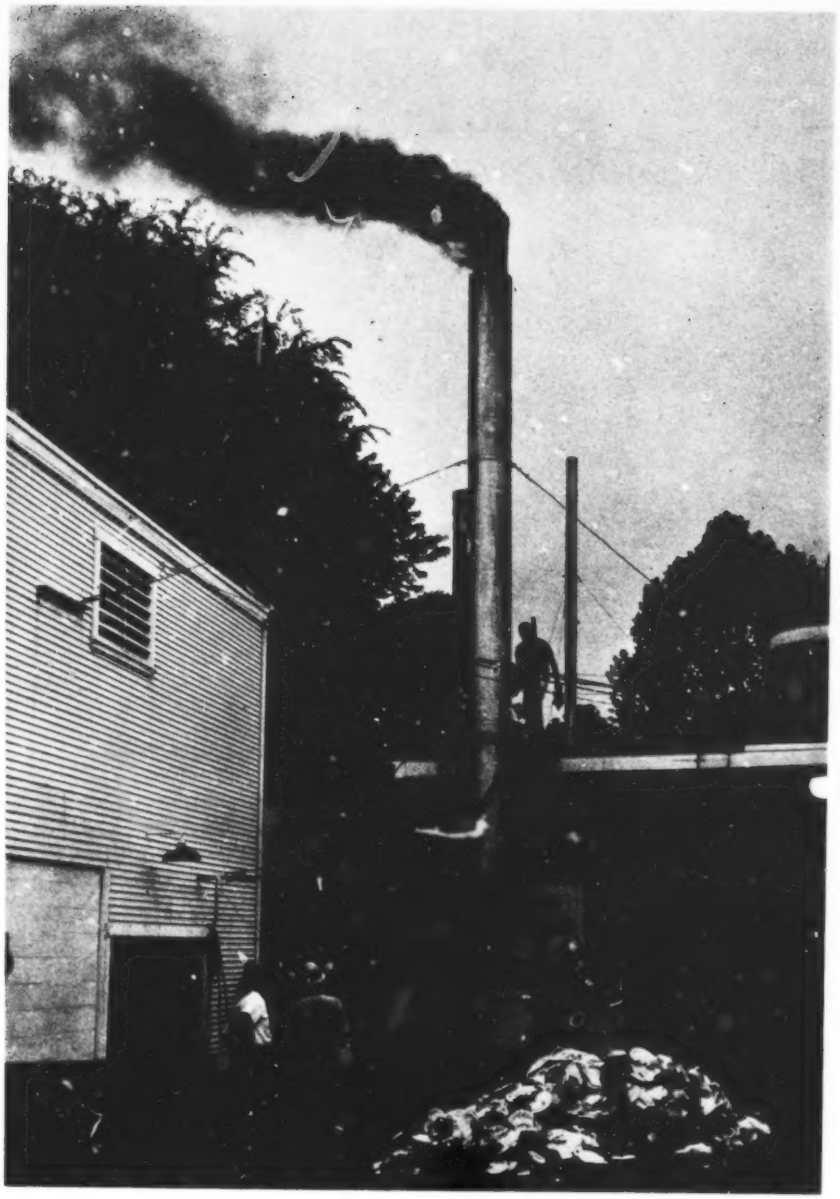
During these emission surveys the engineer is also seeking answers to the second question: How can we reduce pollution from this source? He may propose changes — in a fuel, or in a process, or in a design. He modifies, adjusts, and sometimes invents, in an effort to evolve a system that fulfills its function efficiently without needlessly polluting the air.

Many potential sources of air pollution are under survey: heating units for industrial operations, electric power stations, asphalt-processing plants, large-capacity incinerators, open-burning dumps, household heating units, and motor vehicles. These sources are sampled for total hydrocarbons, polynuclear hydrocarbons, total particulate matter, carbon monoxide, carbon dioxide, nitrogen oxides, sulfur oxides, and formaldehyde. Analytical techniques for field measurements of other contaminants are being developed.

An extensive study of emissions from the manufacture of mineral acid and alkali is being conducted as a joint project with the Manufacturing Chemists Association. Another major survey, performed in cooperation with the U. S. Bureau of Mines, entails emission sampling at large coal-burning power plants.



Surveying emissions from a hot-asphalt road-mix plant



Pollutants pour from the stack of a commercial incinerator

A Typical Problem:

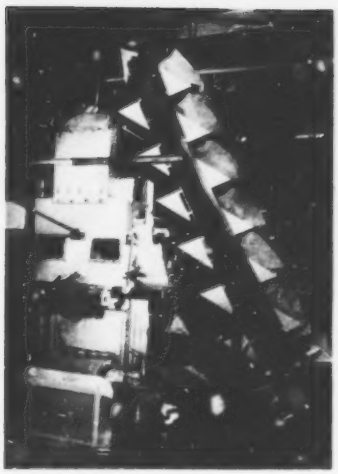
AIR POLLUTION FROM INCINERATORS

For centuries the burning of waste materials has loaded the atmosphere with soot, smoke, flyash, gases, and odorous materials. The incineration of wastes, since it sometimes involves a multitude of burning operations within or near populated areas, often contributes heavily to community air pollution problems.

Some cities have attempted to reduce the total impact of incineration on the community atmosphere by banning the use of 'backyard' incinerators. (This exemplifies one basic method of pollution control — eliminating the air-polluting source.) For disposing of industrial and municipal wastes, however, the use of the large-capacity incinerator is widespread and is expected to increase. No other known method so efficiently reduces the tremendous volumes of refuse that accumulate daily in industrial processing and in urban living. Although alternative methods have been introduced, the incinerator will remain a principal means of waste disposal.

We may consider the incinerator as a typical problem for the air pollution engineer. It involves the basic elements of many combustion processes: an operator feeds material into a combustion unit, from which a gas stream discharges through a stack. The engineer's aim is to determine the effects of incinerator design and operating practices on the discharge of pollutants in this gas stream.

Fuel of uniform composition is prepared for laboratory tests



. . . and fed to the combustion chamber at a constant rate

As their chief research vehicle, PHS engineers have constructed a large laboratory-model multiple-chamber incinerator. The basic incinerator facility can be adjusted to test new design features and changes in basic furnace geometry. In these tests, engineers alter the size and shape of the experimental unit by adding or removing sections of the walls and arches. They systematically vary the waste materials used as fuel, to determine the effects of fuel composition and moisture content.

They also study operational factors, such as the amount and distribution of combustion air, the rate at which the fuel is burned, the amount of fuel used in the individual charges, and the stoking processes. A typical operational problem in the large-scale installations arises when untrained operators load a furnace far beyond its capacity and recharge it with fuel prematurely in an effort to 'burn' as much waste material as possible in a limited time period. Wherever possible such problems are resolved by training, so that operators may understand the basic principles of efficient combustion. As another possible solution, work is under way toward the automation of many fueling operations. In this way such factors as combustion temperature and fuel-feeding rate may be pre-set and automatically controlled.

Air pollution studies indicate that 80 to 90 percent of the air pollutants emitted by incinerators can be eliminated by improvements in design and control of operating techniques.

A Growing Problem:

AIR POLLUTION FROM MOTOR VEHICLES

A widespread and uncontrolled source of certain critical air-polluting compounds is the motor vehicle. The increasing movement of automobiles, trucks, and buses on the roadways constitutes a massive source of air pollution, especially in and near our major cities.

In the operation of motor vehicles, as in other types of combustion, fuel is not completely consumed. It escapes into the air by several paths, in the form of gases, vapors, and particles. The engineering problem of eliminating the pollutant-producing factors from even one automobile would encompass many variables:

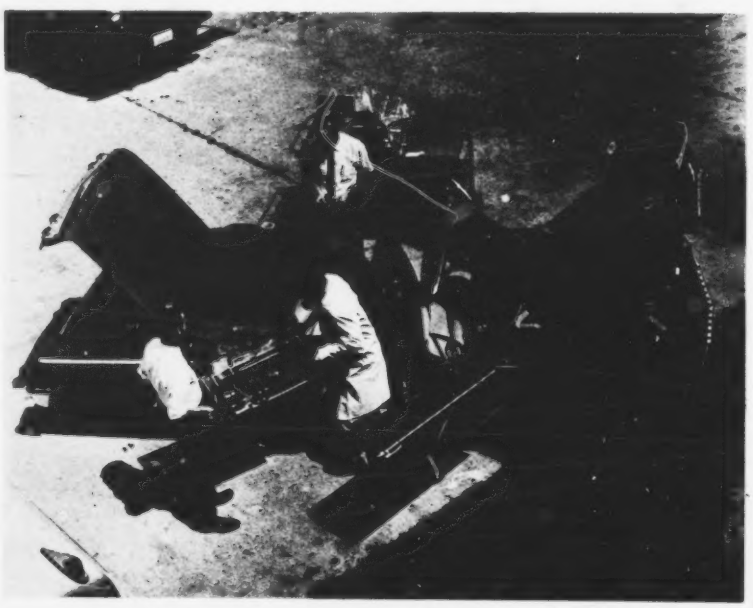
- How old is the vehicle?
- What kind of engine does it have? How many cylinders?
- What kind of fuel is used?
- Is the vehicle well maintained?
- At what speeds is it usually driven?
- Over what kind of route? What kind of terrain?

More than 73 million autos, trucks, and buses traverse our highways daily: each has its own characteristics, and each would provide a different set of answers to such a list of questions.

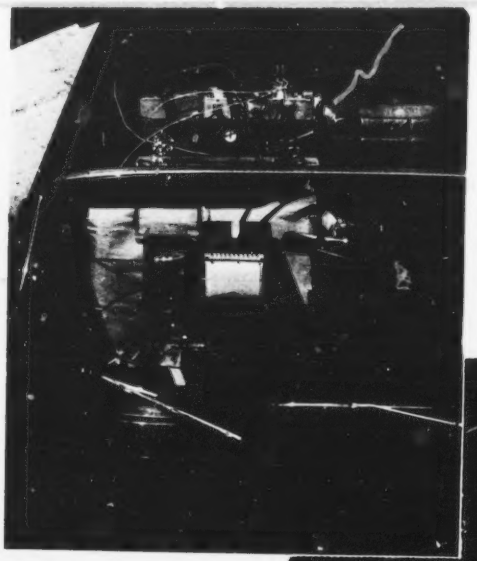
Obviously, researchers must establish a set of average patterns for automotive pollution studies, so that the data gained in testing representative groups of vehicles may be applied to the total vehicle population. This is the purpose of one of the PHS projects in automotive pollution, an intensive series of road-emission studies.

ROAD-EMISSION STUDIES

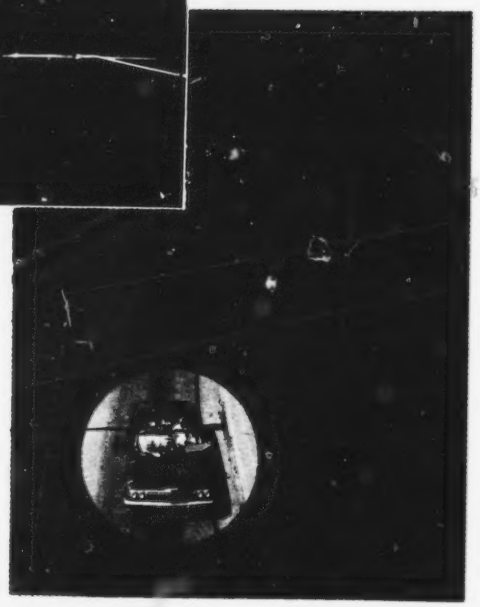
Determining the "typical" constituents of automotive exhausts presents challenging problems, since analyzable exhaust samples must be collected directly from the tailpipes of vehicles in motion on the road. To solve this problem, PHS engineers designed and built a proportional sampler and recording system. Although the sampler and other test equipment involve a web of mechanical and electronic connections that covers the vehicle from bumper to tailpipe, installation requires only a few hours. A proportion of the exhaust from the test vehicle flows through the sampler into a plastic bag partially filled with dry nitrogen, which keeps the exhaust from undergoing chemical change before it is analyzed by chemists in the laboratory. As the samples are collected, instruments record the operating sequence over four test routes: residential, business, arterial, and freeway.



Rigging a vehicle for road-emission tests



Sampler and recorder set to go



. . . on the road

Many kinds of vehicles are tested — old and new models, with standard and automatic transmissions, in varying states of maintenance. Tests with the proportional sampler are scheduled for several major cities, selected because they represent extremes of climate and terrain.

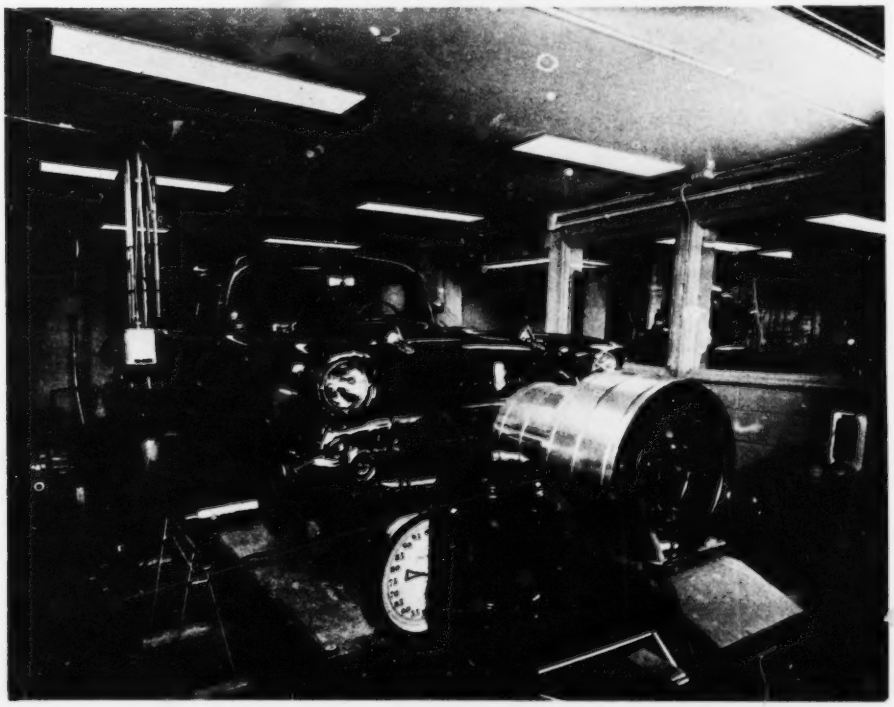
The road-emission tests are providing engineers with two fundamental kinds of information: the typical composition of automotive exhausts, and the effects of various types of traffic routes on the exhaust emissions. For a program whose aim is to reduce air pollution by motor vehicles, these are basic data.

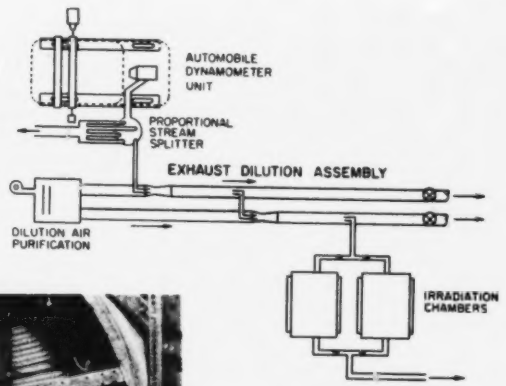
IRRADIATION CHAMBERS

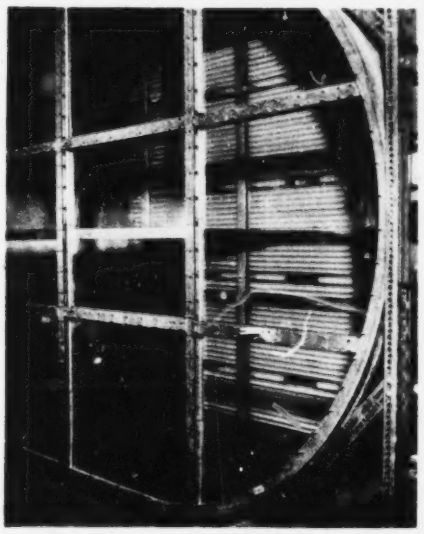
In another major phase of research on automotive air pollution, scientists are creating in the laboratory some of the conditions that occur in our large urban areas with crowded thoroughfares. The aim of this work is to learn what happens when the chemical compounds in exhaust gases are released to the atmosphere.

Scientists have long been aware that some of the compounds found in typical irritating smogs are formed in chemical reactions activated by light from the sun (the resulting pollution is called photochemical smog). To simulate the conditions of outdoor sunlight in their test laboratories, air pollution engineers have constructed an irradiation chamber facility. The facility consists of three major units: a chassis dynamometer, which controls the test vehicle to produce a typical exhaust; a system that purifies large volumes of air to dilute the exhaust gas; and two large irradiation chambers to contain the mixtures of pure air and exhaust gases while they are exposed to artificial sunlight.

The chassis dynamometer is designed to make each test vehicle produce exhaust mixtures as nearly as possible like those discharged by autos on the road. The test vehicle is operated through four driving modes: acceleration, deceleration, cruise, and idle. The dynamometer can be controlled to simulate uphill loads, downhill acceleration, emergency stops, and other driving conditions — it puts a variety of workloads on the test engine.



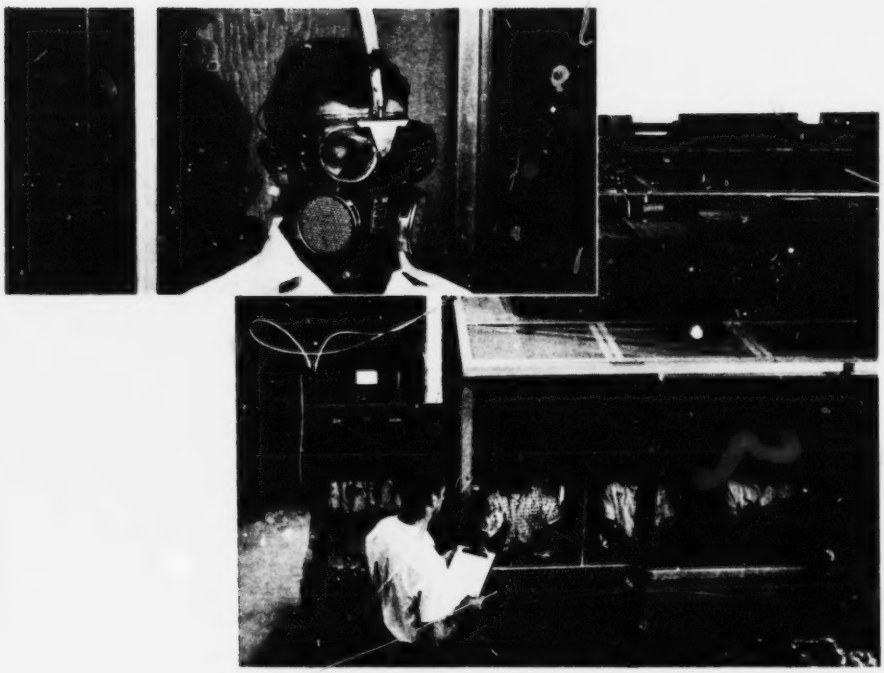




Chamber with fluorescent lights

Before the exhaust from the test vehicle enters the irradiation chamber, it is diluted with purified, conditioned air. Cleanliness, temperature, and relative humidity of the conditioned air duplicate as nearly as possible those encountered in clean atmospheres. The exhaust and the conditioned air are mixed in proportions that might be found out of doors.

Illumination for the chambers is designed to simulate natural noonday sunlight. Banks of fluorescent lights, selected for type and intensity of illumination, shine through the plastic windows of the chamber and 'cook' the mixture of conditioned air and exhaust gases.

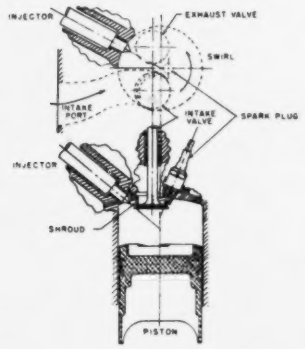


Eye-irritation panel

For studies of the effects of automotive exhausts, the irradiated gas from the chambers is channeled to a battery of exposure facilities, where its effects on vegetation, visibility, and eye irritation are recorded. Periodically members of a volunteer 'eye-irritation panel,' equipped with special exposure masks, record their reactions to various exhaust mixtures. Throughout all tests, chemists monitor the composition of both the irradiated and nonirradiated gases.

The irradiation chamber is a versatile test system. Using it, the engineer can control many aspects of the test environment while he evaluates the effects of changes in such elements as fuel composition, intensity of irradiation, or cycling of the test engine. He can use the irradiation chamber not only to create and evaluate various types of synthetic smogs, but also to test the efficiency of proposed techniques for automotive pollution control.

ENGINE MODIFICATION FOR POLLUTION CONTROL



Much of the work thus far on the control of automotive emissions has been in terms of control devices to be attached to the vehicle. 'Blowby' units are designed to reduce emissions from the crankcase, which contributes about a third of the total air pollution from automobiles. These blowby units are now available and are installed on new-model passenger cars. Progress has been made also on devices for reducing emissions from the tailpipe, which accounts for by far the greatest portion of automotive air pollution (roughly half to two-thirds). As such devices are fully developed, tested, approved, and installed, they will greatly reduce the total load of automotive air pollution.

Scientists are also investigating another, more fundamental, approach to the control of automotive air pollution. Instead of eliminating undesirable emissions after they have been produced, engineers hope to prevent them from being produced at all. Since the engines in widespread use today do generate pollutants, the preventive approach entails the modification and redesign of conventional engines.

A logical first step is to modify the engines in current use, without changing the basic combustion system. In this work engineers are evaluating the effects of changes in carburetion, fuel injection, ignition, air-fuel ratio, and combustion-chamber design. Another possibility is to evolve essentially new engine systems, introducing major changes in the power source of the automobile.

Expanded facilities for engine modification are in preliminary stages at the Robert A. Taft Sanitary Engineering Center. Through such research efforts, scientists hope to reduce air-polluting emissions and at the same time provide more efficient vehicles for America's motorists.

A Problem of Industrial Processing:

CAPTURING POLLUTANT PARTICLES

As air pollution problems increase, industries are seeking more efficient and more economical methods of collecting pollutant particles before they reach the air. Several effective methods for particle capture are in use today in industrial plants across the nation. When they are used, such devices as the electrostatic precipitator and the cyclone separator greatly reduce the emissions from industrial stacks. Filtering the air stream through fabrics is another method of collecting particles before they reach the air, a method especially useful in dry-products operations such as the processing of grains and cements. PHS engineers believe that fabric filtration offers great potential for widespread use in many kinds of industrial plants.

Fabric filters are usually shaped in the form of long, tubular bags, through which the escaping air stream flows. The fabric filter traps dust and particles, which eventually form a cake-like deposit on the sides of the bag. Periodically this deposit is removed from the sides of the bag by mechanical shaking. Without such filtering, the dust might enter the air as polluting particles. (In some processes the recovered material is a useable byproduct.)

Exposure to high temperatures weakens filter fabrics and reduces the useful lifetime of the filter bag. One aim of PHS research on fabric filters, therefore, is to reduce the cost of controlling air pollution by development of sturdy, heat-resistant fabrics and efficient cleaning methods that will minimize fabric wear.

GPO 803-997-3

Fabric filters may be woven from natural fibers (cotton or wool), synthetic fibers (orlon, dacron, silicon-treated glass fiber), or any other suitable material. Cotton or wool filters normally cannot withstand temperatures higher than 230° F. Some silicon-treated glass fibers are operating satisfactorily at about 500° F. Control engineers hope to develop a variety of filter fabrics for long-term use at temperatures over 600° F.

As in incineration studies, research engineers have constructed a laboratory model — a three-compartment baghouse for analysis of design factors and operating techniques.

The testing of filter fiber structure is a continual operation — 24 hours a day, 7 days a week — in the air pollution laboratories. Control engineers are working to reduce both capital and operating costs and thus to promote more widespread use of fabric filters.

The Over-All Problem:

REDUCING AIR POLLUTION

As we have seen,there are several basic methods of reducing air pollution:

- We can simply eliminate the polluting source.
- Or redesign it.
- Or change the operating procedure.
- Or install a control device to keep pollutants from the air.

Combinations of these methods are being applied to the control of air pollution from many sources. PHS engineers are daily at work in laboratory research and on-the-spot investigations. They pinpoint polluting sources and secure air samples for analysis. They design and develop workable systems to control the release of pollutants to the air. They bring to bear on each pollution problem a basic engineering skill: problem-solving through analysis and design.

For effective results, the fight against air pollution must extend beyond the work of engineers and other scientists. This effort calls for action by legislators, civic officials, industrial leaders, and informed citizens. It is the task of everyone who wants to live in clean, clear air.